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of typical implacentals, prepared by alinjection, may be carefully compared with each other and with those of representative Eutheria.

Historical Note.—It is proper to add that the idea of recognizing two antithetical groups according to the presence or absence of a neurocœle, was first formulated by the writer, under the names *cœlianata* and *acœlianata*, on a slip dated November 27, 1883; *cœloneura* and *stereoneura* are dated April 3, 1885. The passage on page 416 in Bell's "Comparative Anatomy and Physiology" (Philadelphia, 1885), commenting on the presence of a cavity in the nervous axis of chordata, was first seen March 13, 1886; but in January of that year, in lectures to students, and in a letter to Prof. J. H. Comstock, the general scheme of a dichotomous classification was presented in substantially the form here given.

SAND-BOULDERS IN THE DRIFT, OR SUBAQUEOUS ORIGIN OF THE DRIFT, IN CENTRAL MISSOURI.[1]

BY J. W. SPENCER, M.A., PH.D., F.G.S.

LOCATION.—During the winter of 1883–84 deep excavations were made in the Drift for foundations of additional buildings at the University of Missouri (lat. 38° 57′ N.; long. 92° 20′ W.). The altitude is seven hundred and thirty-six feet above the Gulf of Mexico. The University is near the southern margin of a rolling prairie, bounded by the large valley of the Hurkson Creek, excavated out of Lower Carboniferous limestones to a depth of one hundred and sixty feet.

2. *Geological Associations.*—The large valley dates back to the close of the Lower Carboniferous epoch. It was subsequently more or less occupied by deposits of the Coal-Measures, which have since been removed, except in some embayments and tributary ravines. Whilst these deposits are not found capping the limestone walls of the valley, yet remnants occur farther away, beneath the Drift-mantle, over the elevations of the rolling country, as shown in a well at the Gardens, just east of the University, where the Carboniferous shales have a thickness of

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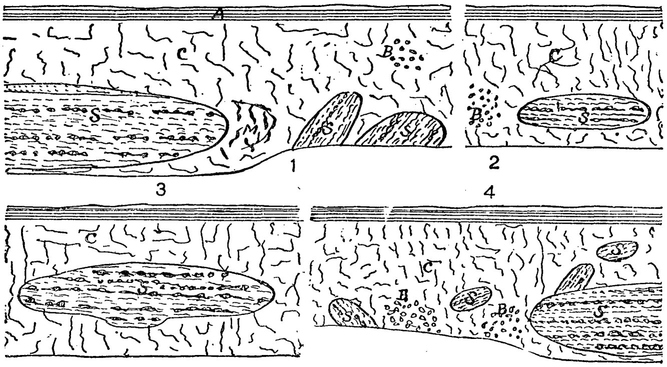
[1] Read before the New York Meeting of the American Association for the Advancement of Science.

thirty-two feet (Professor Tracey). The country to the north is more or less underlaid by coal-basins. The undulations of this region were produced before the deposition of the Drift, as the denudation which removed the Coal-Measures excavated water-courses out of the limestones. To these undulations the Drift conforms, and where cut through by the streams, these flow upon limestone-beds, the higher layers of which abound in chert.

3. *General Character of the Drift.*—At the University Gardens the thickness of the Post-Pliocene deposits reaches twenty-nine feet; at the University, more than twenty-two feet; but in the bed of a stream immediately to the westward it thins out. The upper two to three feet consists of highly-calcareous, clayey soil, different from the poorly-calcareous Drift (A, Fig. 1). The Drift consists of a drab, hard, sandy clay, very much cracked and stained with iron,—bright yellow-red; or occasionally with manganese,—bluish-black (Fig. 1). The staining is superficial, and the mottled appearance has been produced since the deposition of the clay. The clay is rudely stratified, as shown in a wash-out, where a torrent has cut through it (fifteen to twenty feet thick). The lower portion contains fragments of chert from the subjacent rock, and occasional boulders of granite, greenstone, and quartzite, which rarely occur higher in the clay. These boulders seldom reach two feet in diameter, although, eighty to ninety miles to the northward, there is an erratic of about two hundred and twenty-five tons' weight; but the margin of the Drift is not far distant to the southward. Enclosed in the clay,



pebbles of crystalline rocks, from one to four inches in diameter, are occasionally found. In a few places there are concretionary nodules of calcareous matter, similar to those of the loess. There are some included layers of compact blue clay. In one section the remains of a tree were found.

4. *The Mechanical Analysis of the Drift, compared with that of the Local Carboniferous Shale.*—[1]

(*a*) The Drift-clay was found to contain

Free rounded sand,	2–0.2 mm. in diameter	19.8
" " "	0.2–0.1 " "	9.4
Clayey sand,	0.1–0.05 " "	22.8
Clay,	finer	48.0
		100.00

Thus we see that the Drift contains not less than fifty per cent. of free and generally rounded grains of sand, most of which is composed of quartz, with a little that is feldspathic.

(*b*) In the Carboniferous shales there is no distinctly separable sand corresponding to Nos. 1 and 2 of Drift, and none that can be so freely separated as in even No. 3. In short, there are thirty per cent. of sand, at least, in the Drift much coarser and more rounded than that in the local Carboniferous shales, having been transported from the north.

5. *Chemical Analysis of the Drift-Clay* was made by Professor Schweitzer, and found to contain

Silica	77.71
Ferric oxide	3.08
Manganic oxide	0.23
Alumina	10.24
Lime	0.38
Magnesia	0.27
Soda	1.525
Potash	0.575
Phosphoric acid	0.02
Carbonic acid	0.64
Water	5.73
	100.40

6. *Sand-Pockets in the Drift.*—Wherever cuttings are made in the Drift numerous irregular sand-pockets are apt to occur. In most of them, however, the sand is mixed with much clay, but

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[1] The separation was in a Shöne apparatus.

they are quickly recognized owing to their brighter color, being more highly stained red-yellow than the clay, as the coloring-matter appears to have been an after-deposit in the more porous earth.

7. *Sand-Boulders.*—Besides the irregular sand-pockets there are occasional well-formed, rounded boulders of sand, distinctly separated from the clay. Some sections, exposed in the foundations and drains, were two hundred feet or more in length, and ten to eighteen feet deep, and cut through many sand-boulders. Some of the boulders were three to four feet long by one to one and one-half feet thick (Fig. 4); one was fifteen feet long and three thick (Fig. 2); another thirty feet by six (Fig. 3); and a right-angled segment eighteen feet in diameter was taken out of another (Figs. 1 and 4), whose thickness was eight feet; but on top of the boulder there was a deposit of fine stratified sand one and one-half feet thick.

8. *Character of the Sand-Boulders.*—The sand is generally coarse (the grains being one to five millimetres in diameter), with parallel layers of pebbles (one to two inches in diameter). It contains a little clay, which, together with the surfaces of the grains, is brightly stained with iron. The boulders usually lie horizontally, but occasionally they are found thrown upon their edges (Figs. 1 and 4), either in the clay, or, rarely, upon another boulder. Where the boulders have been jammed together they are broken or coalesce. The jamming has caused the boulders to be deposited in various positions, bearing no relationship to the direction of the movement of the pack. These masses of sand cannot be mistaken for decomposed sandstone erratics. Owing to the general occurrence of sand-pockets and boulders scattered through the clay, most of the brick walls built upon the clay foundations are liable to crack, as some portion of them rests upon the yielding strata.

9. *Origin of the Sand-Boulders, and the Subaqueous Origin of the Drift.*—From the stratified character of the sand-boulders quietly resting in the clay, and their rounded form, their subaqueous origin is manifest. The rounded form is the result of the waves wearing and dissolving away the angularity of masses of frozen sand. The transportation was effected by coast and floeberg ice, into which the sandy masses were frozen. The smaller masses of sand commingled with the clay were deposited from

the broken ice-carriers crushed in the jams of many an ice-pack. The presence of the sand-boulders forced upon their edges, and often broken, bears evidence of the violent action of the wind and waves upon the ice. These floes were stranded or sunken in waters which derived at least a part of their mud from the north. The boulders were generally rounded before their stranding, for often the clay between them does not show any sand derived from the removal of their angularities; yet broken fragments may be seen (as at B in sections). Owing to their porosity the amount of ice necessary to lift the masses would not be many times their volume (except at jams they are rarely less than several feet, at least, apart), as their buoyancy would be greatly increased by the frozen water within them; and we know that the waters of the Arctic seas freeze to a depth of seven to eight feet during the long winter, and fresh water somewhat deeper. The unbroken boulders could not have been pushed along, nor could they have been formed so as to have been transported upon the back or within a glacier. These deposits were probably made in a shallow arm of the sea (cut off by the Ozark ridge rising a few hundred feet higher); yet the waters may have been either brackish or even fresher,—as in the Gulf of Obi to-day,—owing to the amount of fresh water pouring into it; and not in a glacial lake held back by an ice-dam south of a vast, extensive lake. Besides, we know that the Mississippi Valley has undergone considerable oscillation and warping since the Tertiary period.

10. *In conclusion*, the presence of sand-boulders of northern origin, as well as the erratics, deposited in a somewhat stratified, transported clay, is a demonstration that the Drift of Central Missouri is of subaqueous origin.

NOTE.—Dr. E. Andrews has observed similar sand- and gravel-boulders in the Drift through which the lake tunnel was driven at Chicago. Some of these contained brackish or sea water. Other pockets are found at Homewood (twenty miles southward) and elsewhere. However, the Drift in Northern Illinois differs from that in Missouri, and contains less free sand, and an absence of the abundance of broken sand-boulders seen at the latter place.